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ME RELATIONS OF ORGANIC MATTER IN SOILS

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SOME RELATIONS OF ORGANIC MATTER IN SOILS

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The effect of lime on the organic matter in soils has been some time one of the leading problems for investigation. The ılts that have been recorded, however, are not consistent. ne investigators have reported that there is a greater acculation of organic matter in limed than in unlimed soil, while ers have stated the contrary. This difference of opinion is surprising when the methods of experimentation, the soil iations, and the climatic conditions are considered. There been, however, too great a tendency to draw conclusions m unreliable data. In many cases, attempts have been made study the effect of lime on the organic matter in soils without nowledge of the composition of the soils before treatment.

In view of the many discrepancies in the reported results, present experiment was designed to ascertain the effect of e on the organic matter in soils under various treatments and pping systems.

HISTORICAL

Wheeler and others (1899)[1] reported that lime decreased percentage of humus in soils under continuous culture of eals. They found also that there was an increase of roots l residual organic matter in limed grass plats as compared to se not limed.

Hess (1901) studied the effect of lime on some of the Pennvania soils. He stated that liming resulted in a diminution of nitrogen.

Kossovich and Tretjakov (1902) stated that the addition of cium carbonate to soil retarded the decomposition of organic tter.

Hartwell and Kellogg (1906) pointed out that the amount of nus in limed plats was less than that in unlimed plats. They ted also that the effect produced by lime upon the organic tter of a given soil was dependable to a considerable extent the degree of acidity or of alkalinity of the soil.

[1] Dates in parenthesis refer to *References Cited*, page. 25.

Pot experiments by Clausen (1906) conducted with clover and oats on sandy soil indicated that applications of lime resulted in a marked nitrogen hunger, especially during dry, hot weather and with non-leguminous crops.

Van Suchtelen (1910) found in laboratory experiments that soils treated with calcium oxide produced less carbon dioxide than did unlimed. soils.

Alway and Trumbull (1910) say:

In a comparison of 22 rotation plots no distinct relation has been found between the composition of the soil and the nature of the rotation. In a long cultivated field the till was found poorer in humus, nitrogen and organic carbon than the lacustral clay. The amounts of the above three constituents found in any of the plots depend more upon the relative proportions of the two types of soil occurring on the plots than upon the previous treatment.

The longer the fields have been kept in grasses mown for hay, the less has been the change in composition of the soil. Continuous bare cultivation along tree rows has caused greater losses than the alternation of fallow and crop in the adjacent fields. The extreme loss of nitrogen, humus and organic carbon in 25 years is about one-third of the amounts originally present in the prairie.

Bradley (1912) conducted pot experiments from which he pointed out that the nitrogen loss was appreciably reduced by legumes.

Mooers, Hampton, and Hunter (1912) reported that the loss of nitrogen was appreciably greater on limed plats than on unlimed plats, and that the effect extended below the depth of plowing. These investigators stated also that there was an increase in percentage of humus on the unlimed sections.

McIntire (1913) writes:

Burnt lime decreased the organic matter when applied alone and lessened the accumulation when applied with manure.

Calcium sulphate and ground limestone increased organic matter.

Each form of lime resulted in an increase of nitrogen content, gypsum, limestone, and burnt lime, being effective in the order named.

Lipman and Blair (1913) reported that in their experiments the limed plats had lost nitrogen to a greater extent than had the unlimed plats.

Gardner (1914) says: "Burnt lime appears to exhaust the humus in the soil more rapidly than ground limestone. Burnt lime with manure gave returns over manure alone. . . . It is desirable that the use of lime or limestone lead to larger supplies of organic matter in the soil."

Swanson (1915) reported results based on the chemical analyses of cultivated and uncultivated soils in seven representative counties in Kansas. He pointed out that the elements

rbon and nitrogen have disappeared from the cultivated soils a larger extent than from the uncultivated soils. He showed at the cultivated soils had lost, in round numbers, from one-th to two-fifths of the nitrogen and from one-fourth to one-ılf of the organic matter.

Potter and Snyder (1916) stated that in a general way the tal nitrogen determinations in their experiments showed that ere was a smaller loss or a greater gain of nitrogen for the ned soils than for the corresponding unlimed soils.

Bear (1916) indicated that quicklime reduced the amount carbon and of nitrogen in the soil.

Potter and Snyder, in a later experiment (1917), concluded at lime in the form of a carbonate, under the conditions of e experiment, appreciably enhanced the rate of decomposition both original soil organic matter and the organic matter stable manures, oats, and clover when added to the soil. They ated that two of the more important results of this were the creased availability of plant food and the more rapid depletion the soil organic matter. They pointed out that the latter fect would be partially and perhaps entirely offset by the fact at with lime larger crops could be grown, which would add ore organic matter as crop residue to the soil.

Breazeale (1917) found that calcium carbonate had a slight structive action upon the organic matter of the soil.

Jensen (1918) stated that in most cases when lime was lded to alfalfa in basins, greater increase in the humus content curred than when alfalfa alone was used.

Christie and Martin (1918) state that it is evident from data nsidered that all soils do not react chemically with lime in e same manner.

Bizzell and Lyon (1918) write: "On Volusia silt loam ad-tion of quicklime increased the amount of carbon dioxide in e soil air. This effect was noticed both on the cropped and cropped tanks. On Dunkirk clay loam quicklime apparently oduced no effect."

Swanson and Latshaw (1919) say:

In the sub-humid section the fields cropped to grain lost one-fourth of nitrogen as compared with the surface soil of the native sod. The al-fa fields contain 5 per cent less nitrogen than the native sod, but 20 cent more than the fields in grain. . . . .

In the semi-arid section the cropped soil has lost one-fifth of the nitrogen compared with the native sod. Alfalfa fields contained 15.7 per cent

more nitrogen than the soils in native sod, and 30 per cent more than the soils continuously cropped. . . . .

In the humid section, the cropped soils have lost 36 per cent of the organic carbon present in the virgin sod and those in alfalfa over 21 per cent.

Lipman and Blair (1920 a) summarized a series of experiments as follows:

Lime in the carbonate form was used on a loam soil at the rate of 1 ton per acre for the first 5 years and 2 tons for the second 5 years in a 5-year rotation of corn, oats, wheat and 2 years of timothy. No legume crops were introduced. Twenty plots with different nitrogen treatment were thus limed and twenty similar plots with parallel nitrogen treatment were left without lime.

The total yields of dry matter and of nitrogen for the 10-year period were essentially the same for the two sections.

Analyses of the soil made soon after the work was started and again at the end of each 5-year period showed that there was a loss of nitrogen from both the limed and unlimed sections. However, the loss from the limed section was distinctly greater than from the unlimed section.

Thus at the end of the 10-year period, there was a positive loss rather than gain from the use of lime.

From this work it would appear that the practice of using lime on light to medium heavy soils, *when leguminous crops are not grown* in the rotation, may be questionable. Under such conditions it is quite possible that a slightly acid reaction may be desirable to prevent the too rapid oxidation of organic matter.

The second five-years period showed a distinct loss in carbon from both series, but a greater loss from the limed than from the unlimed plats.

Lipman and Blair (1920 b) reported also a series of experiments which included rotations with legumes. They pointed out that during the ten years, the limed plots, with only slight exceptions, yielded distinctly larger crops and more total nitrogen than did the unlimed plots. In analyzing the soil they found that in a number of cases the limed plots contained more nitrogen than did the unlimed plots.

The same investigators (Lipman and Blair, 1921) reported the results of experiments in studying the losses of nitrogen and organic carbon from a loam soil (in cylinders with natural drainage) which for twenty years had been under a five-years rotation of corn, oats (two years), wheat, and timothy. They found that in most cases there was a general decline in the nitrogen and the organic carbon content. They pointed out that there was a lower nitrogen and organic carbon content in the limed soils than in the unlimed soils. They stated also that the legume green-manure crops tended to raise the nitrogen content.

It is quite impossible to make any direct comparison of

he literature cited, due to the variations in experimental methods and in representation of results. In fact, in many cases there are no data to substantiate the statements made. Furthermore, the making of comparisons of one plot with another on the sumption that the natural variation in fertility is gradual and iform, is subject to severe criticism. It is likewise impossible study the effect of lime on organic matter in soils without owing the original composition of the soils. Also, conclusions awn from computations based on analyses of soils taken adcent to plats under treatment and assuming that the results tained represent the original analyses of the treated plats, are estionable. However, the general conception expressed by e literature is that plats which have been limed contain less ganic carbon and less nitrogen than do those which have not en limed. There are some exceptions. This conclusion is sed on very limited experimental data.

EXPERIMENTAL

In the present investigation two series of field plats, each 100 acre in size, were used. The plats were sampled both bere and after treatment. The soil was analyzed for inorganic rbon, organic carbon, and nitrogen.

The soil on these plats consists of glacial material reworked y streams and redeposited from glacial lakes (Lyon and Bizzell, 918). Owing to its sedimentary origin it is comparatively ee from stones. The soil has been classified by the United tates Soil Survey as Dunkirk clay loam. It is a heavy, compact oil, and requires careful management. Its average mechanical nalysis is as follows:

	First foot (per cent)	Second foot (per cent)
ne gravel	0.40	0.13
oarse sand	0.63	0.37
edium sand	0.83	0.52
ne sand	1.85	1.05
ery fine sand	12.90	11.27
lt	60.83	53.95
ay	22.63	32.72

The following chemical composition was determined by Lyon and Bizzell from representative samples:

Constituents determined	First foot (per cent)	Second foot (per cent)
Nitrogen (N)	0.134	0.062
Organic carbon (C)	1.190	0.300
Calcium oxide (CaO)	0.340	0.280
Magnesium oxide (MgO)	0.350	0.450
Potassium oxide (K_2O)	1.830	2.360
Sodium oxide (Na_2O)	0.860	0.860
Phosphoric anhydride (P_2O_5)	0.084	0.079
Sulfur trioxide (SO_3)	0.084	0.053
Carbon dioxide (CO_2)	0.030	0.020
Lime requirement* (CaO) in parts per million	1,222	1,285
Lime requirement (CaO) in pounds per acre foot†	4,454	4,918

* The Veitch method was used for the determination of lime requirement.
† Calculated from weight of soil as 3,645,000 pounds of dry soil per acre foot in the first foot of soil, and 3,827,500 pounds in the second foot.

SOIL SAMPLING

The plats in Series I were sampled both before and after the ten-years period. Soil samples were taken from each plat to a depth of four feet, each foot being kept separate. Six borings were made on each plat. The borings for the same foot were carefully mixed together and a 2-quart sample of each foot of each plat was retained. The soil samples were air-dried and placed in tightly sealed jars.

The plats in Series II were sampled before and after the eight-years period according to the following method: Each plat was divided into three parts—N (north), M (middle), and S (south). Each one of these sections was sampled as outlined for the plats in Series I.

Preparation of the sample

The air-dried soil was brought to a uniform condition by breaking up the soil lumps and carefully mixing. A composite sample was taken and was placed in a 1-millimeter sieve. All particles of the soil that did not pass through the 1-millimeter perforations were discarded. A composite sample was taken

m the 1-millimeter sample and was passed through a sieve ring 100 meshes to an inch. In this case it was necessary to nd the soil in order to pass all of it through the perforations.

In the determinations of carbon the 100-mesh sample was d, while the determinations of nitrogen were made from the nillimeter sample. The use of the finer soil in the determinan of carbon was based on the uncertainty of obtaining nplete combustion with the coarser soil.

The determinations were made in duplicate. All duplicates ving a wider discrepancy than 0.02 per cent of carbon and 0.01 cent of nitrogen were discarded.

Total organic carbon

The total organic carbon was determined by the Parr Comstion Method, as described in Bulletin 107 (revised) of the ited States Bureau of Chemistry, page 234.

Total nitrogen

The total nitrogen was determined by the Kjeldahl method. n grams of 1-millimeter soil was digested with 30 cubic centiters of sulfuric acid (specific gravity 1.84) and 0.4 gram of pric sulfate, in 500-cubic-centimeter Kjeldahl Pyrex flasks low heat for twenty minutes. Ten grams of potassium sul- was added and the digestion was continued for three hours. residue was diluted to 350 cubic centimeters of water and nsferred to an 800-cubic-centimeter Kjeldahl flask; from 80 90 cubic centimeters of alkali solution was added and the monia was distilled into 1-10 N sulfuric acid. The distillate, asuring about 200 cubic centimeters, was titrated with 1-10 sodium hydroxide, two or three drops of methyl red solution ng used as an indicator.

SERIES I

Soil treatment and cropping systems

The plats in Series I were under experimentation for a od of ten years, from 1910 to 1919. A statement of the soil

treatment of each plat, and of the cropping systems, is given in table 1:

TABLE I. SOIL TREATMENT AND CROPPING SYSTEMS

Plat	Soil treatment		Cropping system
	Fertilizer	Lime	
7002	Farm manure	None	Rotation without legume
7008	Farm manure	Burnt lime	Rotation without legume
7003	Farm manure	None	No vegetation
7009	Farm manure	Burnt lime	No vegetation
7005	Farm manure	None	Rotation with legume
7011	Farm manure	Burnt lime	Rotation with legume
7006	Farm manure	None	Oats, grass nine years
7012	Farm manure	Burnt lime	Oats, grass nine years
7014	Farm manure and K_2SO_4	None	Rotation without legume
7015	Farm manure and K_2SO_4	Burnt lime	Rotation without legume

The applications of farm manure were made in 1910, 1914, and 1918. The three applications were each at the rate of 10 tons per acre, and were given to the plats that were never planted as well as to the cropped plats. The applications of potassium sulfate were made annually to plats 7014 and 7015 at the rate of 200 pounds per acre. In 1910 and 1915 burnt lime was applied to plats 7008, 7009, 7011, 7012, and 7015, at the rate of 3000 pounds per acre.

The rotation without legume consisted of corn, oats, wheat and grass two years. In the rotation with legume, clover was grown with grass for two years in the first half of the ten-years period, and during the second half of the ten-years period a legume was grown each year as follows: in 1915, soybeans with corn; in 1916, peas with oats; in 1917, vetch with wheat; in 1918 and 1919, clover with grass.

Plats 7003 and 7009 were never planted to any crop, and all vegetation was prevented from growing on them by hoeing

When corn was growing on the plats in rotation, the unplanted plats were hoed at the same time and in the same way as were the plats planted to corn; when other crops were growing on the planted plats, the unplanted plats were merely scraped with a hoe.

The mixtures of grasses used consisted of timothy, Kentucky blue grass, and redtop.

Results

Organic carbon and total nitrogen in plats before and after treatment

The results recorded in tables 2 and 3 represent the averages of duplicate determinations. The percentages of carbon and nitrogen before and after treatment are given, as well as the differences and the percentage of increase or decrease for the ten-years period. The total amounts of carbon and nitrogen added to the plats in manure, have been subtracted from the amounts of carbon and nitrogen determined on analysis after treatment.

The data show that in the first foot, in every case but one, the limed plats contained more organic carbon than did the unlimed plats. This is very significant in the plats kept in grass. Plat 7012, kept in grass and limed, shows an increase of ?.5 per cent of organic carbon in comparison to an increase of ?.5 per cent in plat 7006, which had the same treatment and cropping except that it was not limed. Plat 7002, cropped in rotation but not limed, shows a decrease of 24.5 per cent of organic carbon in comparison to a loss of 3.1 per cent in plat 7008, which had received lime. This difference is not attributed entirely to the lime. Plat 7002 was exposed to greater erosion and more complete drainage than was plat 7008. All plats in rotation show a decrease in organic carbon in the first foot, while there is a marked gain in organic carbon in the first foot in the plats kept permanently in grass.

The use of legumes in rotation did not materially affect the organic carbon content.

Plat 7009, which was kept bare, lost a marked percentage of organic carbon in the first foot.

The percentages of organic carbon in the second foot are

TABLE 2. PER CENT OF ORGANIC CARBON IN PLATS BEFORE AND AFTER TREATMENT. SERIES I

Plat	Treatment	Before treatment		After treatment		Difference		Per cent of increase or decrease	
		First foot	Second foot	First foot	Second foot	First foot	Second foot	First foot	Second foot
7002	Crop rotation Manure	1.242	0.536	0.938	0.457	—0.304	—0.079	—24.5	—14.7
7008	Crop rotation Manure, lime	1.419	0.545	1.375	0.425	—0.044	—0.120	— 3.1	—22.0
7003	No vegetation Manure	....	0.420	1.027	0.348	....	—0.072	....	—17.1
7009	No vegetation Manure, lime	1.477	0.470	1.060	0.425	—0.417	—0.045	—28.2	— 9.6
7005	Crop rotation with legume Manure	....	0.420	1.040	0.365	....	—0.055	....	—13.1
7011	Crop rotation with legume Manure, lime	1.470	0.400	1.377	0.428	—0.093	+0.028	— 6.3	+ 7.0
7006	Grass Manure	1.286	0.500	1.473	0.545	+0.187	+0.045	+14.5	+ 9.0
7012	Grass Manure, lime	1.487	0.575	1.792	0.537	+0.305	—0.038	+20.5	— 6.6
7014	Crop rotation Manure, K_2SO_4	1.462	0.497	1.322	0.605	—0.140	+0.108	— 9.6	+21.7
7015	Crop rotation Manure, K_2SO_4, lime	1.405	0.537	1.309	0.528	—0.096	—0.009	— 6.8	— 1.7

TABLE 3. PER CENT OF TOTAL NITROGEN IN PLATS BEFORE AND AFTER TREATMENT. SERIES 1

Plat	Treatment	Before treatment		After treatment		Difference		Per cent of increase or decrease	
		First foot	Second foot	First foot	Second foot	First foot	Second foot	First foot	Second foot
7002	Crop rotation Manure	0.123	0.077	0.082	0.056	—0.041	—0.021	—33.3	—27.3
7008	Crop rotation Manure, lime	0.128	0.065	0.118	0.054	—0.010	—0.011	— 7.8	—16.9
7003	No vegetation Manure	....	0.077	0.109	0.057	....	—0.020	....	—26.0
7009	No vegetation Manure, lime	0.135	0.070	0.117	0.055	—0.018	—0.015	—13.3	—21.4
7005	Crop rotation with legume Manure	....	0.064	0.115	0.089	....	+0.025	....	+39.1
7011	Crop rotation with legume Manure, lime	0.145	0.069	0.139	0.089	—0.006	+0.020	— 4.1	+29.0
7006	Grass Manure	0.131	0.067	0.137	0.054	+0.006	—0.013	+ 4.6	—19.4
7012	Grass Manure, lime	0.159	0.071	0.161	0.064	+0.002	—0.007	+ 1.2	— 9.9
7014	Crop rotation Manure, K_2SO_4	0.152	0.065	0.125	0.077	—0.027	+0.012	—17.8	+18.5
7015	Crop rotation Manure, K_2SO_4, lime	0.142	0.081	0.125	0.090	—0.017	+0.009	—12.0	+11.1

less consistent than those in the first foot. This inconsistency may be accounted for by lack of soil uniformity.

The limed plats not only contained more organic carbon but also gave higher yields, than the unlimed plats. The yields are expressed in graph form in figure 1 (page 17).

With one exception there was a greater percentage of nitrogen in the limed plats than in the unlimed plats. The plats in rotation all showed a loss of nitrogen in the first foot for the ten-years period, while the plats in grass increased in nitrogen. Plat 7009, which was kept bare, lost a marked percentage of nitrogen in the first foot. Plat 7011, on which the rotation included legumes, lost a smaller percentage of nitrogen in the first foot than did the plats in rotation without legumes.

These results are consistent with the results obtained on the lysimeter tanks (Lyon and Bizzell, 1918). The soil in the lysimeter tanks was obtained from the plats used in these experiments. It was found that the nitrogen in the drainage water from the lysimeter tanks was less where the tank soils had been kept in grass, than in a rotation. It was shown also that the tank soils kept bare lost more nitrogen than the cropped tank soils.

Ratio of carbon to nitrogen in plats before and after treatment

The ratios of carbon to nitrogen in plats before and after treatment are given in table 4. The data show the close relation between these two elements in the soils studied. The ratio was wider in the first foot of soil than in the second foot. The various treatments did not cause any constant change in the carbon nitrogen ratio. The effect, if any, was too inconsistent to be considered significant.

The results compare favorably with those obtained by Hess (1901). He found that the ratio of carbon to nitrogen was not materially affected by the treatment applied. Dyer (1902) also reported that the carbon and nitrogen contents of the upper stratum of the soil were higher than those of the lower stratum and that the ratio of carbon to nitrogen was wider in the upper stratum. Alway and McDole (1916) likewise found that the ratio of carbon to nitrogen was lower in the second foot than in the surface foot.

TABLE 4. RATIOS OF CARBON TO NITROGEN IN PLATS BEFORE AND AFTER TREATMENT. SERIES 1

Plat	Treatment	Carbon-nitrogen ratios			
		Before treatment		After treatment	
		First foot	Second foot	First foot	Second foot
7002	Crop rotation Manure	10.1:1	6.9:1	11.4:1	8.2:1
7008	Crop rotation Manure, lime	11.1:1	8.4:1	11.7:1	7.9:1
7003	No vegetation Manure	.....	5.5:1	.....	6.2:1
7009	No vegetation Manure, lime	10.9:1	6.7:1	9.1:1	7.7:1
7005	Crop rotation with legumes Manure	.....	6.6:1	9.0:1	4.1:1
7011	Crop rotation with legumes Manure, lime	10.1:1	5.8:1	9.9:1	4.8:1
7006	Grass Manure	9.8:1	7.5:1	10.7:1	10.1:1
7012	Grass Manure, lime	9.4:1	8.1:1	11.6:1	8.4:1
7014	Crop rotation Manure, K_2SO_4	9.6:1	7.6:1	10.6:1	7.8:1
7015	Crop rotation Manure, K_2SO_4, lime	9.9:1	6.6:1	10.5:1	5.8:1

Removal of nitrogen from the soil in crops grown on the plats in Series I

The amounts of nitrogen removed in the crops were estimated and are recorded in table 5. The nitrogen is expressed in pounds per acre for the ten-years period.

TABLE 5. AMOUNT OF NITROGEN IN CROPS. SERIES I

Plat	Crop	Fertilizer	Burnt lime (pounds)	Nitrogen in crops (pounds per acre, total for ten years)
7002	Rotation without legume	Farm manure	0	684
7008	Rotation without legume	Farm manure	9,000	798
7005	Rotation with legume	Farm manure	0	817
7011	Rotation with legume	Farm manure	9,000	948
7006	Grass	Farm manure	0	325
7012	Grass	Farm manure	9,000	354
7014	Rotation without legume	Farm manure and K_2SO_4	0	844
7015	Rotation without legume	Farm manure and K_2SO_4	9,000	868

It appears that the nitrogen varies with different crops. The greatest removal of nitrogen was in the crops in rotation with legumes. The hay crops removed less than half the amounts of nitrogen estimated in the crops in rotation with legumes. These results are of extreme importance in considering the total nitrogen in the soils of these plats recorded in table 3, in which, as already stated, it is shown that the plats kept in grass increased in nitrogen in the first foot, while the plats in rotation with legumes and those in rotation without legumes decreased in nitrogen. The fact that less nitrogen was removed from the grass plats may aid in some degree in explaining these differences in percentages of nitrogen.

Total yields of crops on plats in Series I

The total yields of crops in Series I are represented in Figure 1.

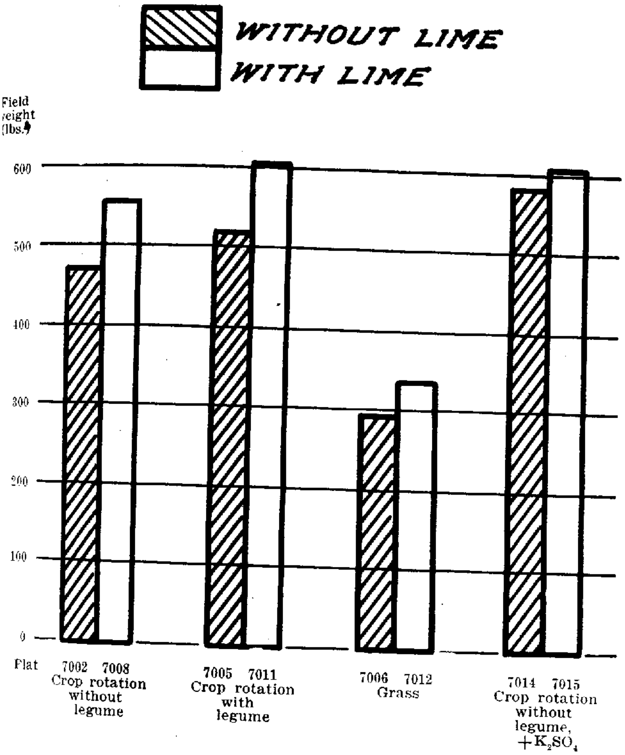

FIG. I. TOTAL PLAT YIELDS FOR TEN-YEARS PERIODS, SERIES I

In every case there was an increase in crop yield on the limed plats over that on the unlimed plats. It seems logical to

assume that an increase in yield is associated with an increase in roots and residual organic matter, which may explain why the organic carbon and the nitrogen were generally higher in the limed plats than in the unlimed plats.

The total yields were less on the plats kept permanently in grass than on the plats in rotation with legumes or on those in rotation without legumes. It has already been pointed out, in tables 2 and 3, that the plats in rotation lost more organic carbon and nitrogen in the first foot than did the grass plats.

SERIES II

In order to obtain further information on the effect of treatment and cropping on the organic carbon and the nitrogen in soils, the plats in Series II, located adjacent to plats in Series I, were analyzed. These plats, as already stated, received approximately the same treatment as the plats in Series I, the only marked differences being that the plats of Series II were started one year later than the plats of Series I, and that they received only two applications of manure.

Only the first foot was analyzed, due to the failure of the second foot in Series I to show any consistent results of experimental value.

The results obtained are recorded in tables 6, 7, and 8. These tables are not discussed separately, due to their close correlation with the results of Series I.

The points emphasized in discussing the results of Series I may well be applied to Series II. However, the results in Series II are much more striking. The limed plats, as was found in Series I, show in general a higher percentage of organic carbon and of nitrogen than do the unlimed plats. The limed plats also gave higher yields than did the unlimed plats. There was a decrease in organic carbon and in nitrogen in the plat cropped under the rotation without legumes, with one exception.

The most interesting phase of these results is that the plat in rotation with legumes showed an increase in nitrogen. The percentages are very significant. Plats 7205 and 7211, in rotation with legumes, increased 4.2 and 6.7 per cent, respectively, in comparison to plats 7202 and 7208, in rotation without legumes, which decreased in nitrogen 12.2 and 7.1 per cent, respectively.

[illegible] Per Cent of Organic Carbon in Plats before and after Treatment. Series 11

Plat	Treatment	Before treatment, First foot, Sections	Before treatment, First foot, Average	After treatment, First foot, Sections	After treatment, First foot, Average	Difference	Per cent of increase or decrease
7202	Crop rotation Manure	N 0.923 M 0.891 S 0.901	0.905	0.879 0.796 0.718	0.798	—0.017	—11.8
7208	Crop rotation Manure, lime	N 0.935 M 0.805 S 0.888	0.876	0.921 0.921 0.876	0.906	+0.030	+ 3.4
7203	No vegetation Manure	N 0.755 M 0.789 S 0.775	0.773	0.626 0.556 0.592	0.591	—0.182	—23.5
7209	No vegetation Manure, lime	N 0.797 M 0.788 S 0.731	0.772	0.821 0.719 0.592	0.711	—0.061	— 7.9
7205	Crop rotation with legume Manure	N 1.064 M 0.982 S 0.966	1.004	1.005 1.005 0.938	0.983	—0.021	— 2.1
7211	Crop rotation with legume Manure, lime	N 1.170 M 1.173 S 0.936	1.093	1.162 1.026 0.066	0.751	—0.342	—31.3
7206	Grass Manure	N 1.026 M 0.948 S 1.012	0.995	1.210 1.102 1.156	1.156	+0.161	+16.2
7212	Grass Manure, lime	N 1.088 M 1.080 S 0.874	1.014	1.387 1.228 1.028	1.214	+0.200	+19.7
7214	Crop rotation Manure, K_2SO_4	N 1.173 M 0.996 S 0.911	1.027	1.087 0.960 0.720	0.923	—0.104	—10.1
7215	Crop rotation Manure, K_2SO_4, lime	N 1.084 M 0.879 S 0.908	0.957	1.062 0.860 0.900	0.941	—0.016	— 1.7

TABLE 7. PER CENT OF TOTAL NITROGEN IN PLATS BEFORE AND AFTER TREATMENT. SERIES II

Plat	Treatment	Before treatment, First foot, Sections	Before treatment, First foot, Average	After treatment, First foot, Sections	After treatment, First foot, Average	Difference	Per cent of increase or decrease
7202	Crop rotation Manure	N 0.120 M 0.115 S 0.110	0.115	0.098 0.105 0.099	0.101	—0.014	—12.2
7208	Crop rotation Manure, lime	N 0.120 M 0.112 S 0.103	0.112	0.109 0.109 0.094	0.104	—0.008	— 7.1
7203	No vegetation Manure	N 0.108 M 0.111 S 0.105	0.108	0.090 0.093 0.087	0.090	—0.018	—16.7
7209	No vegetation Manure, lime	N 0.111 M 0.111 S 0.100	0.107	0.099 0.096 0.079	0.091	—0.016	—15.0
7205	Crop rotation with legume Manure	N 0.122 M 0.128 S 0.103	0.118	0.124 0.119 0.126	0.123	+0.005	+ 4.2
7211	Crop rotation with legume Manure, lime	N 0.126 M 0.124 S 0.110	0.120	0.134 0.134 0.117	0.128	+0.008	+ 6.7
7206	Grass Manure	N 0.118 M 0.114 S 0.108	0.113	0.122 0.127 0.118	0.122	+0.009	+ 8.0
7212	Grass Manure, lime	N 0.129 M 0.115 S 0.112	0.119	0.140 0.124 0.112	0.125	+0.006	+ 5.0
7214	Crop rotation Manure, K_2SO_4	N 0.120 M 0.121 S 0.107	0.116	0.119 0.105 0.103	0.109	—0.007	— 6.0
7215	Crop rotation Manure, K_2SO_4, lime	N 0.113 M 0.111 S 0.101	0.108	0.115 0.101 0.105	0.107	—0.001	— 0.9

TABLE 8. RATIOS OF CARBON TO NITROGEN IN PLATS BEFORE AND AFTER TREATMENT. SERIES II, FIRST FOOT OF SOIL

Plat	Treatment	Carbon-nitrogen ratios	
		Before treatment	After treatment
7202	Crop rotation Manure	7.9:1	7.9:1
7208	Crop rotation Manure, lime	7.8:1	8.7:1
7203	No vegetation Manure	7.2:1	6.6:1
7209	No vegetation Manure, lime	7.2:1	7.9:1
7205	Crop rotation with legume Manure	8.5:1	7.9:1
7211	Crop rotation with legume Manure, lime	9.1:1	8.5:1
7206	Grass Manure	8.8:1	9.5:1
7212	Grass Manure, lime	8.2:1	9.7:1
7214	Crop rotation Manure, K_2SO_4	8.9:1	8.5:1
7215	Crop rotation Manure, K_2SO_4, lime	8.9:1	8.8:1

The plats in grass showed a decided increase in organic ·bon and in nitrogen.

The carbon-nitrogen ratios were lower than those in ·ies I.

moval of nitrogen from the soil in crops grown on the plats in Series II

The amounts of nitrogen removed in the crops grown on plats of Series II were estimated and are recorded in table The nitrogen is expressed in pounds per acre.

The results compare favorably with those obtained in the dy of the plats in Series I. In considering the nitrogen in soils of the plats in rotation with legumes, as recorded in

TABLE 9. AMOUNT OF NITROGEN IN CROPS. SERIES II

Plat	Crop	Fertilizer	Burnt lime (pounds)	Nitrogen in crops (pounds per acre, total for eight years)
7202	Rotation without legume	Farm manure	0	555
7208	Rotation without legume	Farm manure	9,000	714
7205	Rotation with legume	Farm manure	0	690
7211	Rotation with legume	Farm manure	9,000	892
7206	Grass	Farm manure	0	312
7212	Grass	Farm manure	9,000	397
7214	Rotation without legume	Farm manure and K_2SO_4	0	652
7215	Rotation without legume	Farm manure and K_2SO_4	9,000	703

table 7, and that removed by the crops, the advantage from the growing of legumes is fully substantiated. The crops in rotation with legumes removed more nitrogen than did the crops in rotation without legumes. In this connection it is important to note also in table 7 that the plats in rotation with legumes contained more nitrogen than did the plats in rotation without legumes. While the plats kept in grass contained more nitrogen than did the plats in rotation, there is a marked difference in the amount of nitrogen removed by the hay crop as compared with the crops in rotation with legumes. The results show that the rotation with legumes used in these experiments supplied more nitrogen than did the rotation without legumes or the grass.

Total yields of crops on plats in Series II

The total yields of crops in Series II are represented in figure 2. The limed plats show a greater yield than the unlimed plats. This was true also of the plats in Series I. The total yields

owever, of both the limed and the unlimed plats in Series II re less than those in Series I. It may be pointed out here that he plats in Series II contained less organic carbon and nitrogen han the plats in Series I. This may indicate that there is some elation between organic carbon and nitrogen, and yields of rops.

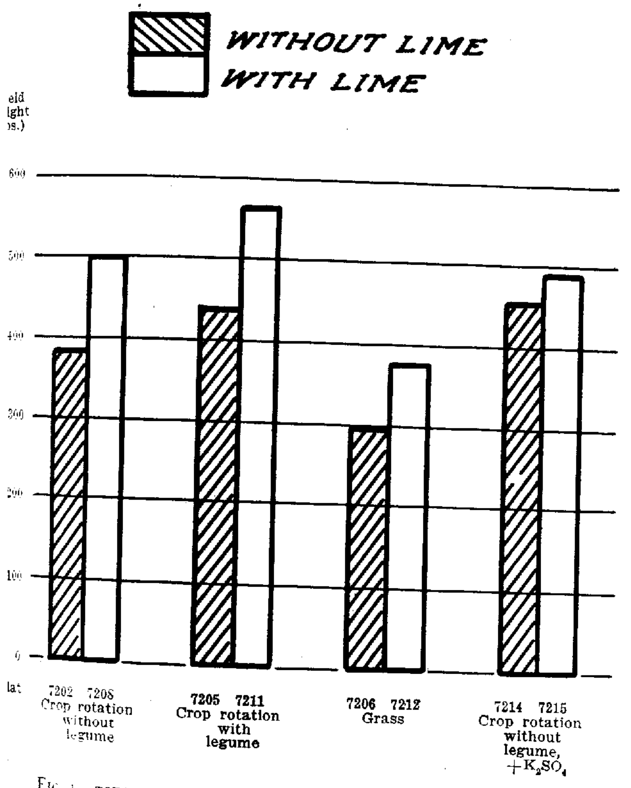

FIG. 2. TOTAL PLAT YIELDS FOR EIGHT-YEARS PERIODS, SERIES II

The most important result shown in figures 1 and 2, as related to the present investigation, is the increase in yields of crops on the limed plats over those on the unlimed plats.

SUMMARY

A study of the effect of various treatments and cropping systems on the organic carbon and the nitrogen in soil is reported in this paper. The soil is classified as a Dunkirk clay loam. The plats were each 1/100 of an acre in size and were arranged in two series. The treatments included manure, potassium sulfate, and lime. The cropping consisted of a rotation without legumes, a rotation with legumes, and grass permanently. The experiment was conducted for periods of eight and ten years, respectively.

The plats were sampled for the first- and second-foot strata before and after treatment.

The organic carbon and the nitrogen were determined.

The results of the two series compared favorably.

In general the limed plats in both series contained more organic carbon and nitrogen than did the unlimed plats.

There was a decrease in organic carbon and in nitrogen at the end of the period of experimentation on the plats in rotation without legumes.

The plats kept in grass showed an increase in organic carbon and in nitrogen.

The plats in rotation with legumes contained more nitrogen than did the plats in rotation without legumes. The plats in rotation with legumes in Series II showed a marked increase in nitrogen. The increase was greater in the limed plats than in the unlimed plats. This fact seems to indicate that the legumes had some influence on the nitrogen content of the soil studied.

The organic carbon and the nitrogen were lower in the plats of Series II than in the plats of Series I.

The limed plats produced higher yields of crops than did the unlimed plats.

The plats in Series I gave higher yields of crops than did the plats in Series II.

The results suggest that there is some relation between organic carbon and nitrogen, and yields of crops.

The crops in rotation with legumes removed more nitrogen om the soil than did the crops in rotation without legumes.

The plats kept in grass lost less nitrogen in the crops than l the plats in rotation with legumes.

There is a close relation between the organic carbon and e nitrogen. The ratio is wider in the first foot of soil than the second foot.

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